Determinants of R&D: Lessons from Literature

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I Introduction

This paper based on a survey of literature, highlights some of the important issues relating to Research and Development activities. The paper begins with the traditional Schumpeterian paradigm emphasising the role of market structure and size of the enterprise in influencing innovative activities. It identifies three sets of factors, namely appropriability, technological opportunity and diffusion that determine R&D. In the next section (Section III) it analyses the relative importance of the three sets of factors and shows that technological opportunity, which is mainly the result of university and government funded research, and diffusion are much more important than appropriability in determining innovative activities of firms. Hence, overemphasis on stricter intellectual property right protection aimed at increasing appropriability could be counter-productive. In this context, it refers to the new Internet revolution that has ushered in peer production and mass collaborations.

Another important issue discussed in this paper relates to the relationship between technology imports and in-house R&D efforts. Sometimes the matter is also posed in terms of either, "make or buy option" or "make and buy decision". If in-house R&D and technology imports are substitutes then technology imports will stand in the way of in-house R&D efforts; if they complement each other then imports of technology becomes an important input to in-house R&D efforts. Section IV discusses these issues.

The section also considers the option available to low R&D spending firms in terms of buying R&D units rather than merely importing technology.

In recent years R&D collaborations, that is, collaborations between R&D units, universities, and research institutions have assumed importance. Several R&D units network with other units and university departments. It is important to find out the nature and characteristics of the units that network and the consequences of networking to the units and other institutions. Section V examines the issues arising out of R&D cooperation between institutions. The section discusses the benefits of collaborations and the associated problems like appropriability, division of costs and difficulties involved in promoting mutual trust. The section also analyses the nature of collaborations between universities and in-house R&D units and the benefits that accrue to them. In addition to formal collaboration between units, there have also been informal collaborations, and the type and consequences of such collaborations are also investigated.

Currently FDI in R&D has become very important. Earlier, most multinationals conducted their R&D in their home countries and if at all they did R&D in the host countries it was for adapting their technology to the host country environment. Later on, they started investing in R&D in advanced countries like the US to benefit from the advanced technological environment in the developed countries. However, during the current decade China and India have emerged as important destinations for R&D. Section VI is devoted to this important newly emerging phenomenon. Section VII draws some lessons from the literature survey.

II Market Structure and Research & Development (R&D) Activities

Neoclassical economics, by and large, ignored R&D activities and issues relating to technological creation and change. As pointed out by Schumpeter (1942) neoclassical economic theory mainly dealt with price competition at the cost of quality competition and sales efforts. However, as stressed by Schumpeter (1942), in capitalist reality what counts is competition from the new commodity, the new technology, the new source of supply, the type of organisation.

One of the important reasons for an economist's obsession with price competition and neglect of innovative activities is due to their hostility to monopolistic market structure and large-scale business. This is mainly due to their fascination with the elegant result the neoclassical theorists derived, namely the monopoly prices are higher and output lower compared to perfect competition. But this inference is valid only if the method and organisation of production in the two market structures, that is, monopoly and perfect competition, are the same. On the contrary, as emphasised by Schumpeter:

"Actually, however, there are superior methods available to the monopolists which either are not available at all to a crowd of competitors or are not available to them readily" (Schumpeter 1942, p. 100).

Accordingly in the Schumpeterian paradigm, market structure is an important determinant of innovative activities. In a perfectly competitive market structure, in the long run, all the firms are expected to earn only normal profits. Under these conditions, firms will not have a surplus to invest in innovative activities. Hence, perfect competition is incompatible with the introduction of new products and processes. On the other hand, under monopoly, firms earn super normal profits, which could be used to develop new products and processes. In the Schumpeterian paradigm, the monopolist gets a reward for taking the risk of introducing new products and processes in the form of monopoly rents. However, the monopoly position is not a safe cushion to relax as other firms would soon catch-up and start competing by introducing other products. Hence, the monopolist has to continuously spend on R&D to keep ahead of other potential competitors. Nevertheless, Schumpeter did not formulate a linear relation between market concentration and innovative activities.

The second important determinant in the Schumpeterian paradigm is the influence of the size of the firm on its R&D activities. Size of the firm has two distinct though related influences on R&D. The first, relates to the existence of minimum economies of size. Most R&D units, to be effective, need minimum threshold investment levels below which no worthwhile technology will either be produced or commercialised. As distinct from minimum size economies, R&D units also enjoy scale economies. The existence of scale economies imply that R&D expenditures of firms need not increase in proportion to firm size but could increase at a rate which is less than proportion to the increase in size. Consequently, R&D intensity or R&D expenditures divided by size would decrease with size. Hence, the size variable captures two effects, namely the threshold effect and the scale effect. It is not possible to capture both effects in a single equation by introducing size as a determinant of R&D as the coefficient of size is positive in one case and could be negative in the other case.

While introducing the role of market structure on R&D, most studies used seller concentration ratios (the ratio of the top four or eight firms in the output of the product/industry) as a proxy for market structure. These studies also hypothesised a linear relationship between seller concentration ratios and R&D. Farber (1981) departed from this practice and introduced buyer concentration ratios in addition to seller concentration ratios in determining inter-industry differences in R&D.

Farber (1981) argues that buyer market structure could also affect the nature of competition in the industry. His main thesis is that the interaction between the buyer and seller market structures would have maximum influence in determining R&D intensities in a given industry. In his model he considers R&D, advertisement intensity and seller concentration ratios as endogenous variables and estimates the model using two stage least squares method. His statistical results show the crucial role played by the interaction variable, namely the interaction of seller and buyer market structures. R&D intensities are high in market structures, which are dominated by both oligopsony and oligopoly. The main reason for this result is the role played by appropriability in determining investments in R&D. The market structure where there are few buyers and few sellers ensures maximum appropriability. By and large, industries like aeronautics, pharmaceuticals, some segments of information and communication technology sector, and certain segments of automotives are R&D intensive. In all these products there are a few firms producing high tech components and they sell to a small group of assemblers who market the final product. In most cases the component manufactures and the dominant companies that buy the components have a long-term strategic relationship and in several cases the final product manufacturers and the high tech component suppliers undertake joint R&D. These R&D intensive sectors that are dominated by oligopoly and oligopsony, enable firms to collaborate in R&D and produce new designs and products. In most of these sectors technological change is very fast and the end-product manufacturing firm buys most of their components and other inputs instead of manufacturing them in-house. Consequently, the value addition of the final product producing firm is not high. In cases where about 80% of the inputs are bought from other firms, the quality of the final product and the technological change in the sector would depend on the changes in the design and the quality of the inputs and components. These characteristics of the sector compel the manufacturers of the final product to actively collaborate with the component and input manufacturers in developing new designs and products.

If there are large number of sellers and very few buyers such strategic relationships between buyers and sellers are not possible as there are too many sellers. In these kinds of markets the sellers could be selling standardised goods and the buyers would be buying them at arm's length. For example, in automotive industry, some of the components could be high-tech that need active collaboration between the automobile producer and the component-manufacturing firm while some of the components like ball bearings could be standardised and produced by many firms. Likewise, in a market structure where there are large number of buyers and very few sellers' active collaboration and high R&D spending is not possible.

III Appropriability, Technological Opportunity and Diffusion

Appropriability is only one of the determinants of R&D. There are other factors that could be of importance like technological opportunity and diffusion. To test for the relative importance of the various determinants of R&D that have been identified in literature it is important to consider all the relevant variables in the same equation. Furthermore, it is desirable to use firm level data rather than the industry level aggregates as firms within an industry differ substantially with regard to R&D.

In this context Cohen and Levinthal (1989) argue that R&D not only generates new technologies, but also enhances the firm's ability in assessing and exploiting existing technology. Firms also invest in R&D in order to successfully utilise external information. External knowledge or outside information could be targeted ones like commissioned research. Knowledge developed by competitors, material suppliers and down stream industries would also positively influence in-house R&D spending. External knowledge could also be less targeted like knowledge developed by universities and publicly funded research labs. Knowledge developed by equipment suppliers and university and government funded labs could be considered as those providing technological opportunity. They provide the input for the firm's R&D.

Cohen and Levinthal (1989) analysed the determinants of R&D intensities (R&D expenditure as a percentage of sales turnover) of firms. They considered a comprehensive set of variables representing appropriability, technology developed by users, government and universities. Furthermore, in order to examine the relative importance of basic and applied research done by the research institutions in influencing the firm's R&D behaviour, they separately considered applied research in areas such as computer science, material technology, equipment technology, agricultural science, material science, medical science and metallurgy. Among basic sciences they considered biology, chemistry, mathematics and physics. Their econometric results showed that while appropriability is important in determining R&D spending by firms, technological opportunity is even more important. Furthermore, among the technological opportunity variables those representing basic sciences emerge more important than the applied ones. The only exception among the applied sciences was computer science. Likewise, university and government funded research turned out to be very important in determining firm's R&D. Moreover, values of regression coefficients were uniformly higher for basic sciences.

Jefferson et al. (2006) investigated the determinants of firm level R&D intensity for 20,000 large, medium and small Chinese enterprises for the years 1995–1999. Using a three equation model they explained R&D intensity, R&D output (ratio of new product sales to total sales) and performance (productivity and profitability). Their results showed that R&D performers are mainly capital intensive large firms. They are mainly concentrated among state owned enterprises and share holding companies, and least concentrated among foreign and overseas enterprises. R&D intensity is influenced by size, market concentration and profitability. They also found a robust association between R&D intensity and new products. The results also show significant returns to new product sales. In their study state owned enterprises are not efficient in knowledge production, however, once they acquire knowledge they are efficient in utilising it.

There are certain other factors that also influence in-house expenditures on R&D. One of them is related to impact on R&D on the firm's performance. Firms that find R&D contributing to their productivity and stock valuation would be motivated to spend more on R&D. Furthermore, expenditures on R&D also depend on corporate governance. In particular, it will depend on stock ownership pattern, debt structure of the firm and its relationship with the banks. These aspects have been analysed by Hosono et al. (2004) in depth. They examined the effect of R&D on stock market performance and total factor productivity growth. For a sample of Japanese firms they found the effect of R&D and market valuation to be positive and significant for the 1990s. During 1980s the effect on stock valuation was positive but the effect on productivity was weal. With regard to corporate governance their study shows that the shareholdings ratio of large shareholders and the leverage ratios are positively correlated with R&D. However, the share of bank loans is negatively correlated with R&D. This result is as expected as the banks are known to have a short horizon. There is also evidence that innovative activities are more in industrial clusters than in stand-alone units (Cainelli and Liso, 2005).

If technological opportunities and spillovers were important, it would be useful to know under what conditions firms gain by them and which types of firms gain. Several studies have shown that productivity of firms depend not only on its own R&D effort, but also on spillovers or pool of scientific knowledge accessible to it. These and related issues were analysed by Kafouros and Buckley (2008). In particular, they seek answer to the following question: When do firms successfully utilize external knowledge to create additional value, and when do they fail to do so? Their data set consists of 138 UK firms for the period 1995–2002. Their study shows that the answer to the question would depend on whether the firm in question is high-tech or low-tech. High-tech firms enjoy good returns on their R&D while the pay-off for the low-tech one is lower. In the case of intra-industry spillovers (impact of R&D done by their intra-industry rivals) also the high-tech firms gain more. In fact their study shows that low-tech firms could even have negative spillovers. This they attribute to the limited ability of the low-tech firms to draw on external scientific knowledge. Likewise, inter-industry spillovers are also higher for high-tech firms. High-tech firms not only benefit from their own R&D, but also from R&D done by other firms. Furthermore, R&D productivity also depend on the size of the firms, here again larger firms benefited more than the smaller ones. Nevertheless, the contribution of spillovers to smaller firms is more than the contribution of their own R&D. This they attribute to the adaptive nature of R&D performed by the smaller firms.

The important role played by technological opportunity and university research in influencing in-house R&D expenditures raise several questions regarding policies that aim to promote appropriability at the cost technological opportunity like strengthening the patent regimes. The World Trade Organisation (WTO) regime has substantially increased the level of intellectual property protection and has made it mandatory for the member nations to introduce product and process patenting and has also increased the duration of the patents. All these measures were demanded by large corporations during the 1980s and 1990s. More recent studies have shown that increased patent protection need not necessarily contribute to more innovative activities. For instance, Allred and Park (2007) based on a detailed study of pharmaceutical industry (an industry wherein patenting is considered very important), found that while increased patent protection could potentially increase domestic patenting by developed country firms, it could adversely affect the patenting of developing country firms. This, in their view, could lead to North-South conflicts, in that stronger patent system may have opposite effects on Northern and Southern innovations and diffusion.

In recent years several corporations have found patenting and enhanced protection to be counterproductive even for Northern firms. As emphasised by Tapscott and Williams (2006) several companies have started opening their doors to the world and have started sharing their resources that they once closely guarded and considered proprietary. Examples include IBM opting for *Linux* an open source platform, Procter & Gamble, Boeing, Dow, DuPont and others registering with and using *InnoCentive* network to solve R&D problems. Several pharmaceutical giants have abandoned their proprietary R&D projects to support open collaborations such as the SNP Consortium and Alliance for Cellular Signalling, and many bio-tech firms have voluntarily placed their DNA related work on open websites. These were the very firms that were demanding stricter patent protection during the 1980s.

The change in the attitudes of large corporations relating to protection of intellectual property and favouring open systems is mainly due to the significant role played by technological opportunity in furthering innovations. University and government funded research in basic and applied sciences have been the main raw material for in-house R&D. If the results of these researches become proprietary then firms will be deprived of the materials out of which new products and processes could be developed. Some of the pharmaceutical firms have also been working on DNA related work. But, by not disclosing them and using them as closely guarded secret they stand in the way of further development of science. On the contrary, if they allow others to build on their research, technological opportunity would grow for R&D. In any case profits for firms come mainly from new products and processes and not from scientific research. By giving access to their scientific research the firms gain.

There is another aspect to this debate that is also important. If the university and academic research output is an important input for in-house R&D units, then it could be argued that the patents of the firms are based not only on their own in-house R&D, but also on academic research. However, academic scholars who prefer publication of their results in professional journals have no share on the revenue emanating from the patents. The patents system under these circumstances appears unfair to academic scholars. On the positive side there is evidence that widespread use of web, Internet and information and communication technologies have encouraged firms to be more open and seek wider collaboration from unrelated third parties. This has encouraged peer production and mass participations in R&D (Tapscott and Williams 2006).

IV In-house R&D and Technology Imports

The relationship between in-house R&D and technology imports has been a much-discussed issue in literature (Odagiri 1983, Siddharthan 1988, 1992). In particular it is important to know whether technology imports complement or substitute in-house R&D efforts. To put it differently, is the decision to undertake R&D and import technology, a make (perform your own R&D) or buy (import technology) decision or make and buy decision? If it turns out to be a make or buy decision, R&D and technology imports would be substitutes. However, if it emerges as a make and buy decision, then they are complementary. Odagiri (1983) hypothesised a negative relationship between in-house R&D and technology imports indicating a substitution relationship. He argued in favour of make or buy proposition. When he tested the proposition for a set of Japanese companies to his surprise he found the relationship to be positive supporting a complementary relationship in favour of the make and buy proposition. In the next step, he classified the sample firms into firms that do innovative research and those that do adaptive research. He found a positive relationship in the sample consisting of firms doing adaptive research but a negative relationship for the sample consisting of firms doing innovative research. Based on these results he concluded that importing technology stands in the way of innovative R&D but not for firms performing adaptive research. In developing countries most firms do mainly adaptive research and therefore one could expect a complementary relationship for these firms.

Siddharthan (1988) for a cross-section of Indian industries and firms for the period (1982–85) analysed the role of technology imports, firm size and age in determining in-house R&D expenditures as a ratio of sales turnover. While doing so he argued that the public (government owned) and private sector firms should not be clubbed as their behaviour relating to R&D and its determinants could be very different. He, therefore, considered them separately. His study shows a positive relationship between the private sector firms R&D and technology imports while no such relationship has been found for the public sector firms. For the private sector the positive relationship between technology imports and R&D is particularly strong for units operating in electronics and textiles. However, the relationship is not strong for firms in chemical industries. This he attributed to the weak intellectual property protection regime that India followed during the early 1980s. For both public and private sector firms, the relationship between firm size and R&D has emerged 'U' shaped indicating that both very small and very large firms spend more on R&D relative to their size. This result is mainly because the nature of R&D performed by the small and large firms are not comparable. The nature and scope of the two sets of R&D are different and in particular the scope of the small firm's R&D is more modest. Furthermore, very small firms have to spend more on R&D relative to the size due to threshold levels in R&D and their expenditures need not increase in proportion to the increase in their size due to the presence of economies of scale in R&D.

Technology transfer could be of two types: first, intra-firm transfer through foreign direct investments and second, inter-firm transfer at arm's length. It would be worthwhile to analyse the relationship between the two modes of transfer and R&D. For a sample of Indian firms, Siddharthan (1992) found both foreign equity participation (intra-firm transfer of technology) and royalty and technical fees (limp-sum payments) were positively related to in-house R&D expenditures and were statistically significant. This indicates that both types of technology imports are complementary to in-house R&D expenditures. This result is in accordance with the hypothesis as the Indian firms do mainly adaptive R&D and for this technology imports is the main input. The results further showed that older firms spend more on R&D than the newer firms.

While discussing the importance of adaptive R&D it is important to introduce the concept of technological paradigms and trajectories. Technological paradigm refers to major changes that alter the manufacturing configurations. Examples of paradigm changes include introduction of biotechnology, information and communications technology. In the established industries also there could be paradigm changes like the shift from batch system of production to conveyor belt method of production in the automobile industry, and change from cross ply tyres to radial tyres. Indian R&D is not directed towards paradigm changes. Instead they import a technological paradigm and introduce changes to suit the market and resource conditions that give them trajectory advantages. For R&D that is aimed at technological trajectory advantages, import of a new technological paradigm is necessary as the trajectories are built on the paradigm.

So far the debate on the relationship between R&D spending and technology imports have been confined to licensing of technology. Some of the firms that spend less on R&D have been adopting another method of acquiring technology, namely acquiring R&D intensive firms. This route is also gaining importance. Blonigen and Taylor (2000) discuss this option in depth. Their paper examines empirical evidence on the relationship between R&D intensity and acquisition activity in the US electronic equipment industry. They found a significant inverse relationship between R&D intensity and acquisition activities. They also present cases of such acquisitions where the chief executives of the firms clearly state that they acquired the firm in question as it is R&D intensive while their own firm was not and the acquisition was a strategy to get access to the R&D output of the firm.

V R&D Collaborations

While acquiring technology the options of a firm is not limited to make in-house and/or buy from another firm. Firms could also go in for R&D collaborations. In recent years R&D collaborations between firms, and between firms and universities have increased manifold. There are several advantages in R&D collaboration. Some of the R&D projects involve huge costs and the outcome of the project is uncertain. Collaboration could address these issues to the benefit of both units. However, there are also important concerns like appropriability, division of costs and problems involved in mutual trust and confidence among collaborating units. The paper by Becker and Dietz (2004) addressed several of these issues. Their results are based on a sample of 2048 German manufacturing firms. They estimate two sets of equations, the first, dealing with the determinants of R&D and the second, determinants of R&D cooperation. They found R&D cooperation very important in determining in-house R&D expenditures. That is, firms that go for collaborative R&D also spend more on in-house R&D. With regard to appropriability and R&D spending, firm specific measures have not emerged important but the laws relating to appropriability are important. Furthermore, firms that are internationally oriented spend more on R&D compared to domestic oriented firms. Among technological opportunity variables, R&D conducted by suppliers and competitors have a significant impact on in-house R&D spending. In short, in-house R&D spending mainly depends on R&D

collaborations with other units, technological opportunities emanating from R&D performed by competitors and suppliers, and international orientation of the firm. Furthermore, they found simultaneity in the relationship between in-house R&D and R&D collaborations. They seem to reinforce each other. The study also shows some unexpected results. While technological opportunities arising from customers and competitors encourage in-house R&D efforts, they adversely affect R&D collaboration. On the other hand, technological opportunities coming from universities and scientific research have a positive influence on collaborations. Furthermore, they found larger firms going in for R&D collaborations. Thus, size has a positive relation with R&D collaborations but a negative relation with R&D intensities.

Several other studies have also found a positive relationship between firm size and R&D collaborations and joint ventures. Hernan et al. (2003) for a sample of more than 5000 European firms found firm size important in positively influencing R&D joint ventures. In addition, they also found R&D intensity of respective sectors significant in influencing the formation of joint ventures in R&D. Furthermore, they found that joint ventures are more likely to emerge in sectors where technological knowledge diffuses fast. In other words, when intellectual property rights are more successfully protected, firms have less incentive to form research joint ventures. This result taken with the earlier results shows that a strong intellectual property regime stands in the way of R&D and joint venture research collaboration. But technology creation depends on these two, namely in-house R&D and research joint ventures. Hence, beyond a point further strengthening the intellectual property regime will prove to be counter productive.

Based on a sample of 2581 Spanish manufacturing firms Lopez (2008), revealed evidence in favour of spillovers in R&D cooperation. The study also showed that R&D cooperative agreements have multiple partners. Two thirds of the firms have cooperation agreement with more than two partners and about one third with more than three partners. Incoming spillovers have a positive and significant impact on the probability of cooperation. However, the level of legal protection in the country has a negative effect on cooperation. Furthermore, as in the earlier studies firm size also plays an important role in promoting R&D cooperation.

For R&D purposes firms not only collaborate with other firms, but also with universities and research institutions. A study by Beers et al. (2008) investigated the determinants of R&D collaborations with public knowledge institutions in Finland and the Netherlands. They found some differences in their results regarding collaboration practices of foreign and domestic firms in Finland and the Netherlands, but the behaviour of the domestic firms turned out to be more or less similar. In particular, the results showed that foreign firms in the Netherlands are less likely to collaborate with public knowledge institutions than the domestic firms. However, this was not so with the Finland sample. In both countries incoming knowledge spillovers influenced positively the probability to cooperate with universities and public funded knowledge institutes. Furthermore, the impetus for collaboration turned out to be for acquisition of basic knowledge than for applied knowledge. This was particularly relevant for the Netherlands.

Most studies use either a dummy variable that takes a value one for units that have R&D collaboration and zero for firms that have no collaboration; some studies also take the number of collaborations as a dependent variable. Negassi (2004) in contrast used the budget spent on R&D collaboration as the measurement of collaboration in his study based on a sample of French firms. He considered R&D cooperation and innovation to be a function of industry and firm specific characteristics. Some of the results of the study confirm the findings of earlier studies like the importance of size and R&D intensity of the units in promoting collaboration. On the other hand, unlike earlier studies Negassi did not find spillovers and technological opportunity conducive for collaborations. With regard to industry level variables, firms functioning in industries that have higher level of FDI inflows went in for more R&D collaborations. When it came to commercial success of innovations, the results didn't indicate a major role for collaborations. Instead the results gave a more important role to other factors like size, human capital, market share and R&D intensity.

While the studies surveyed so far have been giving weight to R&D cooperation, some other studies have been underplaying the importance of R&D cooperation and have been giving more importance to the role of regional spillovers. For example, Fritsch and Franke (2004) investigated the impact of knowledge spillovers and R&D cooperation on innovative activities in three German regions. They used patenting by firms as indicators of innovative activities. They found substantial regional differences with regard to productivities of R&D activities. Furthermore, they found the R&D spillovers from other R&D units operating in the same region to be the main cause of the regional differences. More importantly they found that R&D cooperation played only a minor role as a medium for R&D spillovers.

Consequently, they concluded that agglomeration effects dominate over R&D cooperation effects.

While discussing R&D collaborations between in-house units and universities, government labs and other firms, in addition to analysing the determinants of cooperation, it is equally important to examine the impact of various collaborations. Guellec and Potterie (2004) estimated the long-term impact of various sources of knowledge on multifactor productivity growth for 18 countries during the period 1980–1998. They found that private business funding of university research does not result in higher productivity growth. Based on this result they suggest that it is preferable for universities to keep control of their research agenda and universities should do what they are good at, namely basic research. The results suggest that government should fund basic and innovative research at universities and research labs, which become the basic inputs of in-house R&D research. Nevertheless, R&D units should collaborate among themselves. Further research is needed to verify this interesting result.

Belderbos et al. (2004) while analysing the impact of R&D collaboration took into account the differences in the collaborating partners and the differential impact. They considered the following: partners, competitors, suppliers, customers, universities and research institutes. For this purpose they used a large sample of Dutch innovating firms collected by Community Innovation Survey 1996 and 1998. The study showed that R&D cooperation with suppliers tend to be more of an incremental nature mainly focussed on reducing input costs and increasing labour productivity. Cooperation with universities is mainly aimed at creating novel products and improving productivity of innovative sales. Cooperation with competitors is entered into with more than one objective and they have been resulting in increases in both labour productivity and innovative sales. In contrast, customer cooperation does not seem to influence productivity.

So far the discussion has been confined to formal R&D collaborations. Several firms collaborate with their suppliers and consumers and even undertake joint product/process development without a formal agreement. Bonte and Keilbach (2005) based on a survey data on German innovative firms found that more than 70 per cent of their sample firms are engaged in collaborative innovation activities with their suppliers but only 3 per cent of them are engaged in formal R&D collaborations with their suppliers/customers. They cite earlier studies on German firms that also showed informal exchange of technical knowledge to be the most important mode of innovation collaboration. The study showed that while appropriability conditions are important for both (informal and formal) types of R&D cooperation, legal measures like patents and copyrights do not enhance cooperation. They further find that firms that have been doing R&D continuously have a higher probability of cooperating informally. Before entering into a formal R&D collaboration the firms need to work on the details of appropriability terms. The process is costly. This partly explains the popularity of informal collaborations and sharing of technical knowledge that is more flexible.

It is important to find out the nature of firms that are likely to collaborate with universities and what type of firms gain most through such collaborations. It has been argued that several large corporations have large R&D units that could do innovative research. However, smaller firms lack these facilities and therefore they are the ones who are most likely to approach university departments for collaboration. Motohashi (2005) for a sample of Japanese firms distinguished between complementarity and substitution effects of university industry collaborations. The study showed that firms with higher level of technological capacities in terms of R&D intensity and number of patents are likely to collaborate with the universities. Furthermore, firms that have R&D collaboration with external parties are more likely to tie-up with universities. With regard to the size and age of the enterprise the study showed that smaller and younger firms are more likely to collaborate than the large and older ones. The results relating to the impact of university industry collaborations showed that university professors in Japan are changing their mind set and are actively participating in the commercialisation of their inventions.

There are several entrepreneurial technology firms that would like to collaborate with larger firms. The question here is one of finding out the research standard and suitability of an entrepreneurial R&D firm's seeking collaboration. Katila and Mang (2003) in their study attempt to find answers to this problem, namely when the entrepreneurial companies collaborate during product development. They found that companies that have filed patents have a better chance of entering into successful collaborations. This is because, while filing for patents the company also reveals its technological capability and the character of its innovations. They hypothesise and find that firms that have applied for patents in the project, have higher R&D intensity, and prior collaboration experience with a partner tend to collaborate more.

Some studies (Eraydin 2005) have found that the intensity of their global and local linkages promotes innovativeness. Networks formed with global suppliers and customers also contribute to the formation of industrial clusters, they in turn lead to more networks. In short, studies show three main motives for R&D collaboration: cost and risk sharing, learning from partners, and absorptive capacity of the firm. In this context Lopez (2008) found that the complementarities between partners in a cooperative agreement would also depend on the knowledge base within the firm. Likewise, the absorptive capacity will also depend on its own R&D and knowledge base.

VI FDI in R&D

Till recently multinationals performed most of their R&D in their respective home countries. If at all they established R&D units in host countries it was to adapt their technology and products to the host country environment and market. During the 1980s several firms established R&D units in technologically advanced countries to take advantage of the technological and research environment in the host countries. In more recent years they have also been setting up R&D units in developing countries. The table given below based on the UNCTAD survey shows that China and India have emerged as the most favourable destinations for setting-up R&D units.

Most attractive prospective R&D locations in the UNCTAD survey 2005–09, (per cent of responses)

China	61.8
United States	41.2
India	29.4
Japan	14.7
UK	13.2
Russia	10.3
France	8.8
Germany	5.9
The Netherlands	4.4

Canada	4.4
Singapore	4.4
Taiwan Province of China	4.4
Belgium	2.9
Italy	2.9
Malaysia	2.9
Republic of Korea	2.9
Thailand	2.9
Australia	1.5
Brazil	1.5
Czech Republic	1.5
Ireland	1.5
Israel	1.5
Mexico	1.5
Morocco	1.5
Norway	1.5
Poland	1.5
Romania	1.5
South Africa	1.5
Spain	1.5
Sweden	1.5
Tunisia	1.5
Turkey	1.5
Vietnam	1.5

Most of the developed countries come well below China and India.

Kuemmerle (1999) was one of the first to analyse this emerging phenomenon of FDI in R&D. However, during early 1990s FDI in R&D was mainly confined to the developed countries and in particular to the US. He identified two motives for investing in R&D in host countries. The first, to exploit the technological developments made in the home country. Technology developed in the home country might have to be modified to suit the market and resource conditions of the host country. Hence, the need for R&D. This motive, he called, ‘Home Base Exploiting’ (HBE) R&D. The second motive, which could be more relevant to R&D investments in the US and other technologically advanced countries is to expose the home country firms to the host country's technological environment and enjoy spillovers. This kind of investment in R&D in the host country is mainly meant to increase or add to the intangible assets of the firm. Kuemmerle (1999) termed this motive as 'Home Base Augmenting' (HBA) R&D. The main drivers for HBA investments were technological collaboration and spillovers from existing R&D units in the host country, universities and research institutions, and industrial and technological clusters. His paper identifies the main determinants of the choice between HBE and HBA investments. He found the differential R&D spending relative to the GDP between the home and host countries and the skill levels of population between the countries as important determinants in deciding in favour of HBA. While these variables might explain the FDI in R&D to developed and technologically advanced countries, they cannot explain flows to developing countries as most developing countries have lower R&D spending and lower levels of skill intensity. Nevertheless, in recent years the developing countries have emerged as the main host countries and it is important to explain this phenomenon.

Shimizutani and Todo (2008) tried a variant of HBA and HBE hypothesis for Japanese FDI in R&D. They made a distinction between R and D. They considered basic and applied research as R, and design and development as D. This distinction is somewhat similar to that of HBA and HBE distinction. The purpose of their study was to analyse the determinants of location choice of Japanese overseas FDI in R&D. They found that FDI in R&D would more likely to be of R type if the host country R&D expenditures to GDP was high. For D type of investments this variable would not be relevant. Based on a sample during the period 1996–2001, they found R type of investment in technology frontier countries and in some newly industrialised countries like South Korea. On the other hand they attribute the underlying factor for the rapid increase in R&D investments in China to the country's local market based on brisk economic growth. They also found that Japanese firms performed R type of R&D in countries where Japanese subsidiaries have been investing heavily in R&D. Host country's GDP had a positive impact on both types of R&D. Furthermore, the probability of performing R&D of both types was negatively related to the distance of the country from Japan.

Kurokawa et al. (2007) analysed the determinants of Japanese investments in R&D in the US. Even though the paper dealt with investments in the US, some of the variables that they have introduced could be relevant in explaining investments in developing countries also. In fact they could be considered as host country variables rather than US variables. To Kurokawa et al., if the objective of setting-up of the R&D unit was to strengthen their R&D capabilities where some of the technologies of the host country could be more advanced, take advantage of the better technological environment in the host country, employ and utilise researchers in the host country, monitor technologies in the host country, and to create global R&D synergies then the unit is classified as HBA unit. On the other hand if the objective was to respond to the needs of the host country market and establish an integrated system from R&D, production to sales, then it is HBE type. The study showed that the choice of HBA would depend on the importance given to R&D alliance, namely collaborative R&D projects with local firms, universities and research institutions. It would also depend on the method of evaluation of R&D personnel and autonomy granted to R&D units. These very same factors could emerge important for investments in developing countries like China and India and similar questions could be asked from units established in other developing countries.

Patents granted based on overseas innovations could also be considered to analyse overseas R&D activities. Belderbos (2001) examines the patents of 231 large and medium Japanese electronic good manufacturing firms to analyse the determinants of R&D activities of Japanese subsidiaries. His dependent variable is the number of patents granted based on overseas innovations during 1990–93. The results showed that R&D intensity of the firm measured by patents to sales ratio, internationalisation of their manufacturing operations, size and export intensities are significant determinants. He concluded that these results support both HBA and HBE hypothesis.

MNEs operating in the host countries could be classified under four heads: (1) those having only manufacturing units with no R&D facilities, (2) those conducting R&D at the manufacturing plant without a separate R&D unit, (3) those conducting R&D at the plant site and also having a separate R&D unit, and (4) conducting R&D solely at the research laboratory. Ito and Wakasugi (2007) examine the factors affecting the choice of R&D functions among Japanese affiliates. They consider the second type as support oriented R&D and the next two types (3 and 4) as knowledge sourcing R&D. They found that propensity to export is an important factor in deciding to establish an R&D unit. Parent firms with large R&D establishments tended to establish R&D units in the host country. Host country technological capabilities like the royalty receipts of the host country as a percentage of GDP and proportion of researchers in the work force also strongly contributed to the establishment of R&D units. In particular the technological status contributed to having a knowledge sourcing R&D unit.

The paper by Hegde and Hicks (2008) dealt with the globalisation of the US corporate R&D and analysed the relevance of foreign market size, science and technological capabilities of the host countries and the R&D atmosphere in the host countries. Their primary interest was in the relationship between the overseas R&D activities of the US firms and host country attributes. In this context they distinguish between initiation of foreign R&D and its intensity and they measure them using both expenditure and patent data. They capture the technological strength of the host country by the number of USPTO patents invented in the host country and not assigned to US companies or inventors. In analysing the determinants, in addition to the size and technological strength of the host country, they also introduce the national output of scientific and engineering articles published in professional forums. This variable measures the world-class scientific enterprise in the host country. They found all the three variables significant in explaining US overseas R&D investments. In addition they also used industry dummies and found electronics and computers industry, and in the traditional sectors transport, metals, and industrial machinery important. The introduction of the three determinants, they claim, explains the emerging R&D investments in China and India. In 1990 China and India accounted for only 0.1% of FDI in R&D. This figure increased to 2.3% in 2003. During this period, China and India increased their science and engineering publication output from about

4.5 to 7.2% while Europe's numbers hovered around half of the total share of non-U.S. articles. They conclude that public investments in science and technology institutions are more likely to attract investments in R&D than manufacturing investments.

The determinants of R&D for domestic enterprises and MNE affiliates could differ and in addition they could also be influenced by shifts in economic policies of the government. Kumar and Aggarwal (2005) analysed the determinants of R&D for a sample of Indian local enterprises and MNEs operating in India. They conducted this exercise for both the pre and post economic reform periods to examine whether the determinants of R&D changed after the introduction of the reforms. They found that after reforms local Indian enterprises were more sensitive to performing R&D to absorb imported technology and to facilitate external orientation. However, the R&D behaviour of MNEs did not alter consequent to economic reforms. Local firms R&D was also influenced by capital goods imports and their R&D was strongly influenced by outward orientation and overseas investments.

VII Lessons From Literature

During the last decade, the importance of intellectual property protection and the role of appropriability have been occupying a central place in most of the discussions on R&D. The developing countries have enacted laws to enhance intellectual property protection in accordance with the WTO guidelines. It was, more or less, assumed that enhanced intellectual property protection would facilitate investments in R&D and the world would be better off. However, the results of our survey do not support this view. The results show that investments in R&D depend much more on technological opportunity and diffusion and therefore sole emphasis on appropriability and strengthening patent protection could be counterproductive. Diffusion and patent protection are negatively related and the results of the survey clearly show that diffusion contributes much more to investments in R&D than appropriability. The most important factor contributing to investments in R&D is technological opportunity, which is created by university and government aided research.

Innovations, in addition to depending on in-house R&D efforts also depend on R&D cooperation and collaboration with other units including universities. Furthermore, units that have been collaborating with other science and technology establishments tend to invest more in their in-house R&D units. Here again, appropriability and enhanced patent protection does not play a significant role in fostering R&D collaborations. Stricter laws have become a stumbling block forcing the units to forge informal collaborations to bypass the strict regulations.

In this context, several studies show the crucial role of agglomerations in promoting investments in R&D. Units are much more innovative if they belong to an agglomeration compared to stand-alone units. Some studies emphasise the importance of regional and knowledge spillovers. Clusters have several advantages, like availability of trained personnel, spillovers, and better infrastructure facilities. Among these factors studies emphasise spillovers and diffusion arising out of frequent contacts among personnel. This has encouraged firms to forge informal collaborations with units in the same agglomeration.

The relationship between in-house R&D and technology imports has been discussed in literature at length. In order to understand the relationship it is important to distinguish between developments in technological paradigms (new manufacturing configurations) and incremental technological trajectory changes introduced to adapt the new paradigm to suit the market and resource conditions. Studies surveyed show that R&D units in developing countries mainly perform adaptive R&D and enjoy technological trajectory advantages. For them technology imports are necessary to perform R&D and reap trajectory benefits. Thus, import restrictions on technology imports imposed by earlier import substitution regimes adversely affected innovative activities.

Several multinationals have set-up R&D units in developing countries like China and India either as stand-alone units or jointly with research institutions and R&D units in these countries. The obvious motivation is that in the perception of the MNE it is more efficient to perform that kind of R&D in India and China than in the home country. The host countries also benefit from them in terms of spillovers and opportunities for international networking. The benefits of FDI in R&D to host country institutions and firms as well as the costs involved have not yet been analysed in detail. Future research should concentrate on this important area.

The traditional notion of an R&D unit acting in secrecy, possessive of its research findings and inventions, and jealously guarding its intellectual property is fast changing. The emerging trends are in favour of networking with other units and institutions, participate in open source platforms, take advantage of peer production/creation and benefit from increased technological opportunity. Evidence indicates a change in the emphasis from increasing appropriability through tougher patent laws to enhancing technological opportunity.

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